Rapid Hydrographic, Optical and Microstructure Surveys on the Continental Shelf and Slope

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LONG-TERM GOALS

To understand the dynamics of mesoscale circulation over the continental shelf and slope, with an emphasis on fronts, jets, eddies and topographic influences. To examine the relationship between circulation processes and the spatial distributions of mixing and optical properties over the continental margin.

OBJECTIVES

To investigate the relationship between mesoscale circulation and spatial distributions of mixing and optical properties over the continental shelf and slope. To understand how lateral variations in the mixing and optical fields influence variations in vertical mixing processes observed at a mid-shelf location. Specific objectives of this project are: to determine the characteristics and spatial scales of density, velocity, mixing and optical properties on the continental shelf and slope in the Middle Atlantic Bight south of Cape Cod; to investigate how distributions of mixing and optical properties depend on characteristics of the mesoscale coastal circulation; to describe how the characteristics and distributions of mixing and optical properties on the shelf differ between seasons and relate these differences to seasonal contrasts in coastal circulation and water-column structure.

APPROACH

As part of the Coastal Mixing and Optics (CMO) Accelerated Research Initiative, we made contemporaneous measurements of density, light absorption/attenuation and microstructure using sensors mounted on SeaSoar, a towed undulating measurement platform. The SeaSoar sensor suite includes a dual-sensor Sea-Bird CTD, a nine-wavelength spectral absorption and attenuation meter (WET Labs ac-9) and a new microstructure instrument (MicroSoar). Horizontal velocity is measured using a 300-kHz shipborne acoustic Doppler current profiler (ADCP). We conducted rapid surveys using R/V Endeavor during two 21-day field experiments in the Middle Atlantic Bight centered near 40.5°N, 70.5°W, south of Cape Cod. We completed a summer survey, when the shelf is stratified,from 14-Aug to 1-Sep 1996 and a spring survey, when the shelf water tends to be more mixed, from 25-Apr to 15-May 1997. During each field experiment we collected data from repeated large-region surveys over a roughly 70 x 80 km box completed in about 2 days. Alternating with the large-region surveys, measurements were concentrated in a small box (roughly 25 x 25 km completed in 14 hours) centered around a mid-shelf location where the physical and optical fields were intensively sampled by our CMO colleagues using moored instrumentation and vertical profiling from a stationary ship.

WORK COMPLETED

We processed data from the instruments aboard SeaSoar, which made approximately 34,900 vertical profiles of the water column over the continental shelf and slope during the CMO cruises, and from the shipboard ADCP. Hydrographic fields obtained from the CTD onboard SeaSoar were reported in O'Malley et al. (1998), online at http://diana.oce.orst.edu/cmoweb/csr/main.html. During this year, we continued to analyze our own extensive hydrographic, velocity and bio-optical data sets and to collaborate with other CMO PIs.

Velocity data from the ADCP was processed using bottom tracking, DGPS ship's navigation and high-quality ship's heading from the R/V Endeavor's TANS system, and was reported in Pierce et al. (1998), online at http://diana.oce.orst.edu/cmoweb/adcp/main.html. Velocity data from our two 21-day CMO cruises together with moored velocity data from Levine and Boyd (SAS PRIMER, Jul-Sep 1996), Pickart (Shelfbreak PRIMER, Dec 1995 to Feb 1997), and Beardsley and Gawarkiewicz (Shelfbreak PRIMER, Jul-Aug 1996) have been used to estimate barotropic tidal currents in the CMO region. Five tidal constituents (M2, S2, K1, O1, and N2) are fit in time and space to the velocity data using a least-squares harmonic model with cubic surface-fitting Chebyshev polynomials (101 unknowns). A singular value decomposition is used to solve this possibly rank-deficient inverse problem. Two improvements on the published methods are: different levels of uncertainty associated with each input velocity data point (e.g., bottom-tracked vs. navigation-referenced ADCP) are explicitly taken into account; and Chebyshev rather than ordinary polynomials are used as basis functions, offering numerical advantages and greater accuracy for under-determined cases. Some details were presented at the 2000 Ocean Sciences meeting and a manuscript is in preparation.

MicroSoar data from the fast-response capillary microconductivity probe sampling at 2 kHz, from co-located temperature and pressure sensors, and from a three-axis accelerometer have been processed. Details of the MicroSoar design appear in May (1997) and a description of the MicroSoar system and techniques for obtaining fields of temperature variance dissipation rate (chi), Cox number and heat flux is in Dillon et al. (2000). Finally, the entire CMO MicroSoar data set, including vertical sections and horizontal maps of microstructure properties, has been reported in Erofeev et al. (1998), online at http://diana.oce.orst.edu/cmoweb/micro/main.html.

Processing of optical data from the nine-wavelength absorption and attenuation meter (WETLabs ac-9) flown aboard SeaSoar has required new processing techniques. As reported in Barth and Bogucki (2000), it is critical to calculate a time-dependent lag between when the optical properties were measured and when the CTD sensors sampled the same water parcel so that the optical data can be corrected for known dependence on temperature (and to a lesser extent on salinity). A data report has been published (Simeon et al., 2000), a subset of which is available online at http://diana.oce.orst.edu/cmoweb/ac9/main.html. The optical data set has been submitted to the World Ocean Optical Database (WOOD).

RESULTS

Time-dependent maps of the three-dimensional distributions of hydrographic, velocity and optical properties over the shelf and slope in the Middle Atlantic Bight south of Cape Cod show the importance of advection and mesoscale (with horizontal dimensions of the size of the Rossby radius) and sub-mesoscale structure on vertical distributions at a mid-shelf location. Examples include intrusions from offshore at both the bottom and near the surface of warm, salty and relatively clear slope water, mesoscale meanders from the shelfbreak front and jet, and packets of internal solitary waves propagating shoreward and displacing the thermocline and deep chlorophyll maximum at the base of the pycnocline. The spring 1997 cruise captured the restratification of the water column and an anomalous shoreward extent of a warm, salty bottom boundary layer driven by eastward near-bottom flow likely associated with a backward-breaking unstable meander of the shelfbreak front and jet.

The barotropic tide in this region is dominated by the M2 and K1 constituents, with 65% and 12% of the total tidal variance. The size of the M2 varies strongly across the region, with semi-major axes of 0.30 m/s at the northeast corner (40.7°N, 70.0°W) but decreasing to 0.02 m/s at the southwest corner (39.9°N, 71.0°W). The M2(K1) solutions have accuracies of 0.016(0.026) m/s rms, validated independently by comparison with current meter data omitted from the model. After subtraction of the best barotropic tidal estimate, we also re-applied the method to the residual, in order to examine the baroclinic tidal signature. The barotropic tidal prediction is also used to produce subtidal velocity fields from the measured shipboard ADCP velocities, revealing the details of the frontal jets and eddies over the shelf and slope.

D. Bogucki (Postdoctoral Research Associate) is investigating particulate resuspension induced by Internal Solitary Waves (ISW) during the 1996 CMO experiment. The analysis is primarily based on mooring, tripod and SeaSoar data. ISW-induced resuspension was related to retarded flow under the wave footprint and corresponded to the largest resuspension events observed in the experiment (Bogucki et al., 2000). Both mode-1 and mode-2 ISWs were observed. The mode-2 waves appear to be locally generated by mode-1 ISWs. To our knowledge, these are the first observations of mode-2 waves on the continental shelf. Both mode-1 and mode-2 ISWs were responsible for resuspension. This situation may be common for other shallow seas.

Dillon et al. (2000) described the details of a new high-frequency turbulence measuring instrument, MicroSoar. With appropriate assumptions about the local T-S relation, measurements of microscale conductivity fluctuations can often be used to directly determine temperature dissipation rate, the Cox number and the scaler diathermal turbulent diffusivity. Compared with conventional quasi-free-fall tethered vertically profiling instruments, MicroSoar's major advantage lies in its ability to sample large fluid volumes and large geographic areas in a short time. A cross-shelf section in the Middle Atlantic Bight south of Cape Cod, Massachusetts, reveals springtime restratification of the surface layer over cold shelf water bounded on the offshore side by the stratified shelfbreak front. The temperature variance dissipation rate indicates strong mixing at the base of the surface mixed layer and at the seasonal thermocline. A branch of the high dissipation rate in the thermocline deepens and connects with very high dissipation rates near the bottom. Cox numbers were large near the shelfbreak front and diffusivities were as large as 10^{-3} m^2 s^{-1}, two orders of magnitude larger than mid-ocean thermocline diffusivities.

J. Simeon (OSU Graduate Student), with the guidance of J. Barth, S. Pegau (OSU) and C. Roesler (Bigelow), is decomposing the multi-wavelength light absorption measurements made from SeaSoar into contributions from the major absorbing components of seawater: phytoplankton; gelbstoff or colored dissolved organic material (CDOM); and colored particulate material or tripton). Horizontal maps at 10 m from Spring 1997 show the relationship between the physical and bio-optical fields (Figure 1). A strong correspondance between low salinity and high gelbstoff in the northwest corner and along the top of the survey region indicates a recent river origin for this water. Most of the light absorption (a_{T-w}) is due to particulates, phytoplankton (a_ϕ) and tripton (a_t). To bound the spatial scales for which optical tracers can be utilized, horizontal decorrelation lengthscales were quantified for the hydrographic and IOP parameters. Temperature, beam attenuation and component absorption at 440 nm have decorrelation lengthscales of 3 km on the shelf.

IMPACT/APPLICATIONS

By combining the simultaneous measurement of hydrography, velocity, optical properties and fine-scale temperature variance from over the continental margin, we contribute to understanding the dynamics of the interactions between these fields. This will lead to a greater predictive capability for specifying the distributions and their time-dependent behavior over the continental margin.

TRANSITIONS

The MicroSoar technology is being packaged for use by R. Zaneveld (OSU), D. Hebert (URI) and C. Paulson and H. Wijesekera (OSU). The MODAPS+ data acquisition and power supply system is being used by others (T. Cowles, OSU; C. Roesler, UConn) and is available from WETLabs, Inc. The Optical Oceanography group at OSU (Zaneveld, Pegau) is using our SeaSoar optical data to investigate whether optical properties on the shelf can be treated as conservative tracers (Pegau et al., 2000).

RELATED PROJECTS

We are collaborating with CMO colleagues who are using moored instrumentation (S. Lentz, T. Dickey) and vertical profiling from a stationary ship (R. Zaneveld, S. Pegau) to address the ARI's goals. We are also working with scientists (M. Levine) who participated in the ONR PRIMER “Synthetic Aperture Sonar” conducted near the CMO central site.

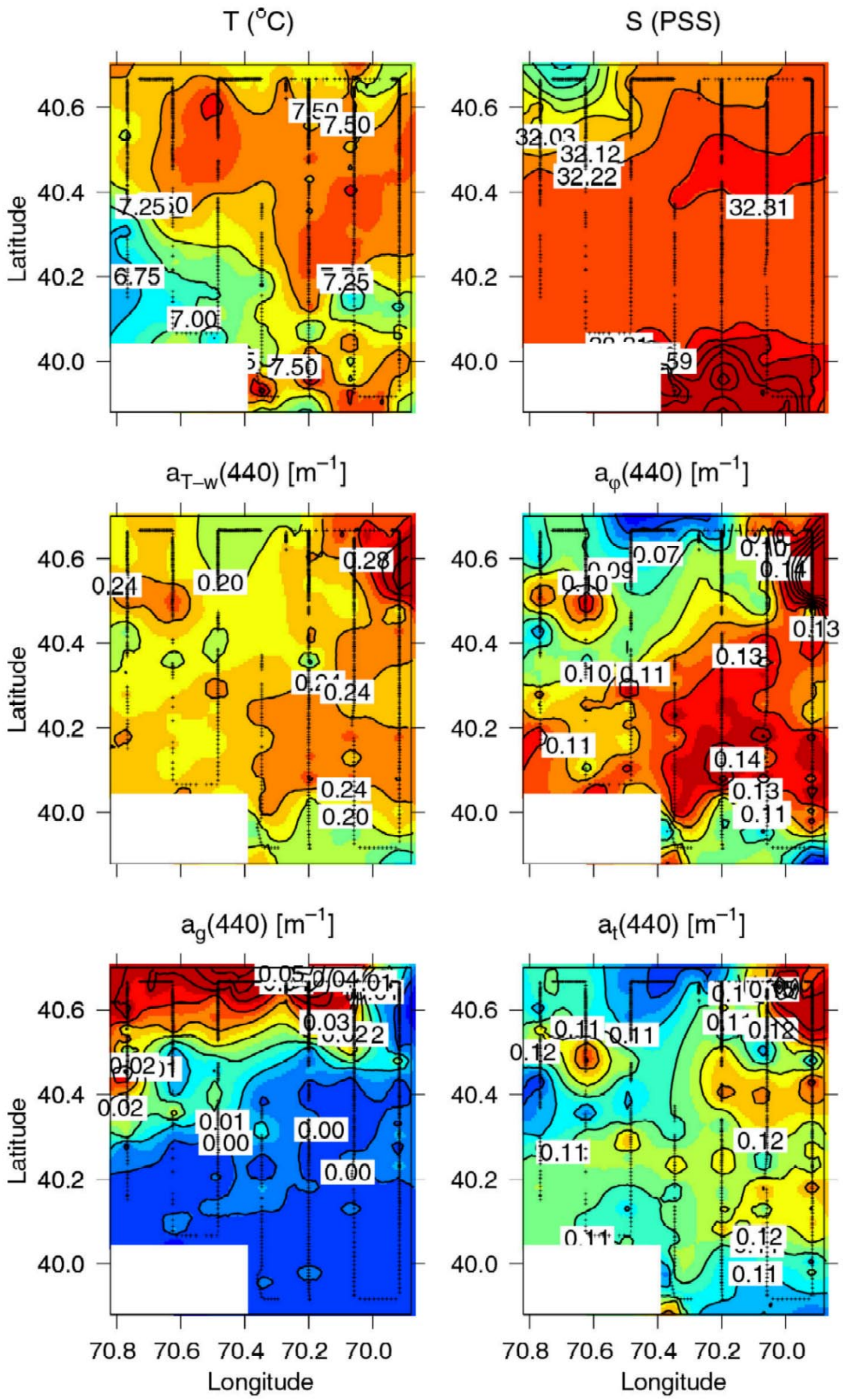

Figure 1. Maps at 10 m from 4-6 May 1997 over the continental shelf south of Cape Cod in the Middle Atlantic Bight showing the relationship between the hydrographic fields (T, S), the inherent optical properties at 440 nm (total minus water light absorption, a_{T-w}) and the modeled absorption components phytoplankton (a_ϕ), tripton (a_t) and gelbstoff (or Colored Dissolved Organic Material, a_g). Sample locations along the ship track are indicated. Note the strong correspondance between low salinity and high gelbstoff in the northwest corner and along the top of the survey region, indicative of a recent river origin for this water.

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